Response to The Subcommittee on Energy
Committee on Science:

Assessing Progress in Advanced Technologies for Vehicles and Fuels

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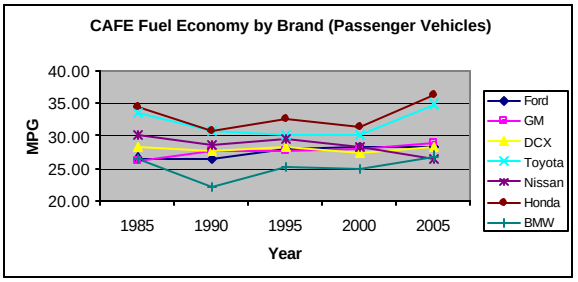
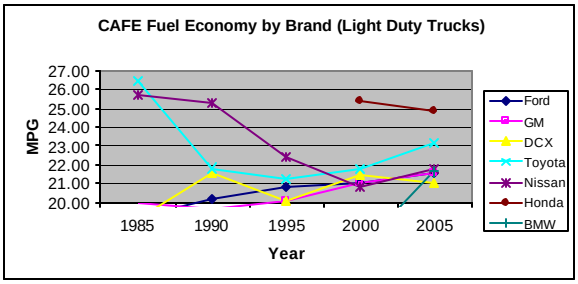
The following are the written answers to two questions posed by The Honorable Judy Biggert, Chairman, Subcommittee on Energy of the Committee on Science.

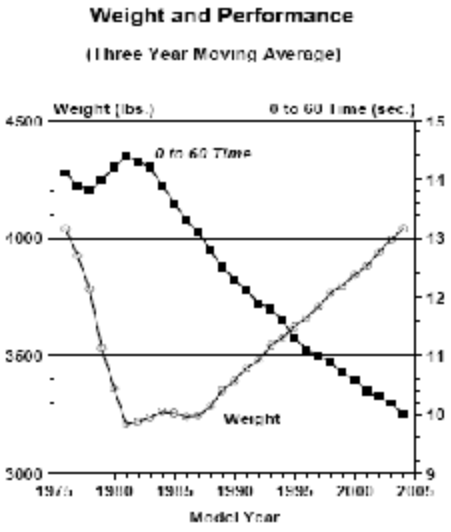
Question 1:
The auto industry in recent years has generally used technological improvements to increase performance instead of fuel efficiency. What would be required to lead automakers to apply technology advancements to improving fuel economy?

Commercially successful manufacturers design, develop, build and sell vehicles that resonate with the core values of the consumer and that meet the needs of their lifestage in the current and expected future business and economic environment. The automakers will design, develop, produce and sell whatever vehicles the consumer will buy. Advanced technologies have been applied to date to hold the CAFE performance of the U.S. light vehicle fleet at or close to regulatory levels while providing increased acceleration, levels of safety and interior feature content. If large numbers of consumers were to demand instead, or in addition, greater levels of fuel economy, the manufacturers would be able to respond with a broader range of hybrids, diesels, downsized and turbocharged gasoline engines, displacement on demand, etc. At this point in time, however, it is our view that while fuel economy is increasingly important to many consumers, most still place a higher priority on other vehicle features and attributes. If and when fuel economy becomes a higher priority for the consumer, the vehicle manufacturers can and will respond.

Trends in CAFÉ, Acceleration Performance and Vehicle Weight.







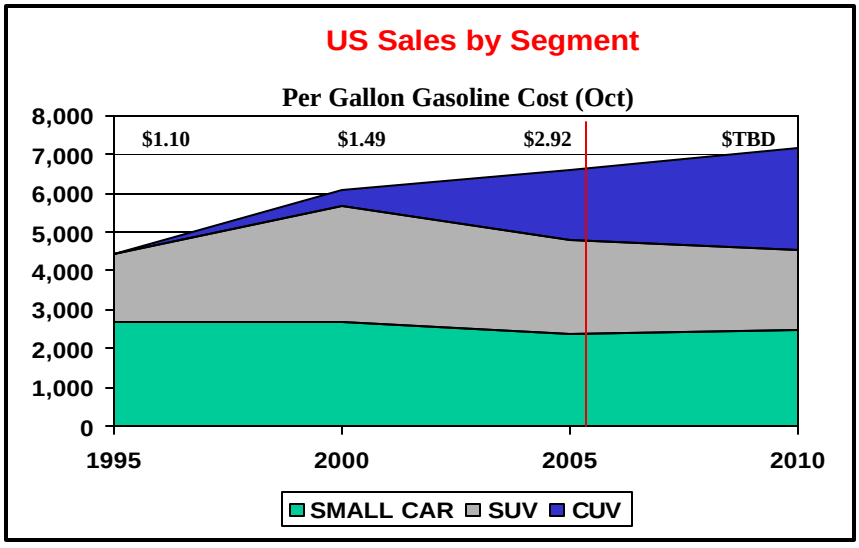
Source: EPA Report on Light Duty Automotive Technology and Fuel Economy Trends: 1975-2005, July 2005

What will increase the consumer's demand for fuel economy?

Demand for fuel-saving technologies will increase when fuel conservation creates a greater resonance with the consumer's core values. Our research indicates that the Baby Boomers, the bulk of today's new-car buying public, have core values that center around the need for economic, physical and social survival. They have an inherent need to prepare themselves to deal with any and all foreseeable adversities. The need for mobility itself is a key aspect of survival, and viewed as an unalienable right by virtually all Americans. The need to travel in perceived security under any adverse driving conditions gives rise to demand for four wheel drive. The need to command and control their driving environment gives rise to demand for a high seating position. The need to be better than the next person gives rise to demand for fast accelerating vehicles. The desire for perceived safety gives rise to demand for massive vehicles. Hence the demand for large, truck-based SUVs.

However, fuel prices are currently very high, at least when compared to historical levels. For the moment, the high fuel costs have not been assimilated into the family budgets of most consumers, and demand is shifting to vehicles with attributes similar to the SUV, but on more fuel efficient front-wheel drive-based passenger car platforms (so-called "crossover utility vehicles" or "CUVs"). (It is interesting to note that small car sales are NOT increasing at the same time due to their lack of appeal to the core values of the consumer.) This momentum towards more efficient vehicles could be sustained if consumers cannot adjust to higher gasoline prices. It is our view, that if prices stay at these current levels and don't go higher, some of the momentum will diminish and consumers will go back to older buying patterns.

U.S. Sales of SUVs, CUVs and Small Cars
(thousands of units)



Source: Global Insight, Inc.

It must be recognized that the consumer has so far had an amazing capability, over the longer term, to assimilate high fuel prices into the family budget. On the policy side, artificially high fuel prices due to taxation have not been acceptable due to the repressive nature of such taxation and the negative impact on the popularity amongst the voters of those who support them. (In this area, Americans are unique compared to consumers in many other major consuming countries.) Therefore, we need to find other, lasting solutions. Let's take a look at some of the consumer core values and how they can be reached by advanced technologies.

The Baby Boomer consumer, as part of his/her value for survival, has a strong competitive ethic embodied in the need to be better than the next person. Hybrids, which do not provide a financial payback due to their inherently high cost and sensitivity to duty-cycles, are being re-engineered to return some fuel economy benefits while also offering high-levels of acceleration. The diesel engine, which offers much higher levels of acceleration-producing torque as well as fuel economy when compared to a gasoline engine, can offer equal if not better acceleration than a gasoline hybrid while more reliably providing the fuel economy benefits desired by society.

Acceleration Times of Various Hybrids Compared to Their Base Vehicle

0-60 MPH times (seconds)			
Model	Base	Hybrid	Result
Honda Civic	9.5	11.3	Neg
Honda Accord	7.9	7.4	Pos
Ford Escape	9.1	9.4	Neg
Lexus RX	7.8	7.3	Pos
Lexus GS	5.7	5.2	Pos
Toyota Highlander	7.6	7.3	Pos
07 Toyota Camry	6.7	7.0 est.	Neg

Various sources

"It's very important to continue pursuing substantial reductions in fuel consumption and emissions, while continuing to improve performance and driving pleasure. Our customers wouldn't have it any other way" said Lexus Vice President of Marketing Mark Templin. The result is a level of acceleration performance similar to a V-8 engine

The need for survival also causes a person to seek a safe and secure environment. Conventional wisdom supports the notion that a safe vehicle is a heavy vehicle. Parents who want to ensure the safety of their children prefer to carry them around in a heavy vehicle such as an SUV. There is a current Country and Western song that even states "I'm not going to sacrifice the safety of my family just to save a gallon of gas." The relationship between safe and heavy needs to be discredited before one can expect a large shift away from heavy vehicles.

Another aspect of survival is to ensure the safety and security of one's self and one's children. This includes preparation of a safe and secure future. A fact-based public education program about the need to conserve all forms of energy, including but not limited to the energy consumed for mobility, would be expected to increase demand for fuel-saving technologies. Education programs have been successful in reducing smoking, seat belt utilization and reductions in drunk

driving. Why not similar programs in the schools, on television and other media in support of energy conservation?

Successful education programs can include:

- Fact-based propositions as to the net benefits to the individuals and society
- Fact-based education as to the full costs of less efficient practices and preferences
- Model behavior by role models, including movie stars, pop idols, politicians, corporate fleets
- "Placement" of strategic messages within popular culture and media: TV, Movies, newspapers, etc.
- Requirements for obvious energy saving measures in all aspects of life can provide a constant reinforcement of the need to conserve in everything we do. In Europe and China, the lights in hotel hallways are off unless the presence of a person is detected. When you walk down the hall, the lights follow you, turning on ahead of you and turning off a few minutes after you pass. In America, lights burn brightly, often 24 hours per day.
- Classroom instruction during the formative childhood years

Each of these channels of influence should work to imbed the message that the core value of "survival" in adverse conditions (whatever they may be) is enhanced through energy-conserving solutions. That is, the core value of survival needs to encompass reduced dependency on a single source of energy. Survival also needs to be linked to minimization of greenhouse gases just as people came to accept the need to reduce toxic and smog-forming emissions in the 1960s.

Such educational programs should be enhanced with feebate and registration-tax programs. Under a feebate program, fees on less fuel-efficient programs would be used to subsidize the purchase of more fuel efficient vehicles in a manner similar to what is done now in some states to reward safe drivers with a discount on insurance, the discount being funded by higher rates for unsafe drivers. Recurring carbon- or fuel-consumption based registration or "circulation" taxes, paid every year by the car owner, based on the fuel consumption rating of the vehicle, can also encourage the purchase of more fuel efficient new as well as used cars. Education programs coupled with cost-savings through government managed stick and carrot programs can be effective.

Another way to reach the core values of the consumer is to change the perception of mobility itself. It will be futile to try to reduce the consumer demand for mobility. A successful strategy could be instead to offer virtual mobility as an alternative. High speed communications provided through fiber optic networks into every home will reduce the waiting time for internet-based communications exchanges. Telecommuting and video conferencing can become an even more viable alternative to physical commuting and shopping with higher upload and download speeds. Perhaps even a system of rewarding corporations (as opposed to the individual) for establishing satellite offices or encouraging "working from home" would go a long way to reducing fuel consumption. What is required is to make the consumer realize that this is a convenient and effective alternative form of mobility.

Question 2a:
What hurdles must hybrids, flex fuel, and hydrogen-powered vehicles clear before the automobile industry, industry analysts, and the automotive press accept these technologies and consumers buy them?

The primary caveat associated with the adoption of any new technology is that any negative attributes should be totally transparent to the consumer. That is, there should be:

- *No cost penalty over the life of the vehicle*
- *No reliability/durability penalty*
- *No range penalty*
- *No functional penalty*
- *No convenience penalty*

Flex-fuel (FFV) vehicles have been accepted by the public for many years, and they are cost competitive and 'transparent' to the consumer in all aspects except range when fueled with the lower energy content E85. Since 1995, over Six million have been produced and sold in North America. The incremental cost for their production is very small, and is largely associated with the use of a low-cost sensor and selection of fuel and intake system materials that are compatible with the fuel. The incentive has primarily been the CAFE credit given the vehicle manufacturer for selling such vehicles.

Production of FFVs by Major U.S. Vehicle Manufacturers
1995 - 2005

Year	DCX	FORD	GM	Annual Total	Cum. Total
1995	346	85,158	131,095	216,599	216,599
1996	794	122,468	138,471	261,733	478,332
1997	28,923	146,504	126,799	302,226	780,558
1998	163,120	234,102	187,625	584,847	1,365,405
1999	208,248	264,720	185,956	658,924	2,024,329
2000	185,782	257,470	188,131	634,063	2,658,392
2001	320,172	294,812	89,916	704,900	3,363,292
2002	314,267	294,984	248,861	858,112	4,221,404
2003	202,980	255,044	282,873	740,897	4,962,301
2004	103,638	217,117	244,437	565,192	5,527,493
2005	124,367	205,770	146,415	476,552	6,004,045

Source: Global Insight Powertrain Database

In order for these FFV vehicles to make a difference in our national petroleum demand, the ethanol-based fuel E85 must be more widely available at a cost competitive with that of gasoline.

There is less energy per gallon of ethanol than gasoline or diesel, so the cost must be adjusted to give the consumer a cost-per-mile that is equal or less than gasoline in order to gain widespread acceptance of the fuel. It is well-known within the government that of the approximately 175,000 refueling stations in the U.S., there are only 4,992 alternative fuels stations reported by DOE, and of those, only 637 offer E85.[1]

Hydrogen has greater challenges than FFV, although some are similar in nature. Ford and BMW have demonstrated that it is possible to offer hydrogen powered vehicles today, burning the fuel in an internal combustion engine. However, hydrogen fuel requires new fuel production, distribution and vehicle fueling systems. In addition, as hydrogen is currently understood, it would require some changes in consumer behavior to operate. On-board storage issues result in reduced range and some restrictions on the access of these vehicles to all public places. In addition to these challenges, the major hurdle to creating demand for them is the almost total lack of a hydrogen refueling infrastructure.

Technologically, there are a number of challenges to the production, distribution and storage of hydrogen so that there is a net benefit to society. Briefly stated, they are:

- **Production**: By most methods, the production and compression of hydrogen will create more greenhouse gas and use more energy than is saved by burning it in an engine. The theoretically high efficiencies of the fuel cell are needed to make a net gain possible with hydrogen fuel. Achievement of these high efficiencies at commercially viable cost levels is one of the major goals of fuel cell developers.

- **Distribution**: Hydrogen is the smallest natural molecule known to man. It can therefore leak out of the smallest holes, even finding its way through the very small crevices and cracks that exist in many metals and joints that contain other liquids and larger gas molecules very well. The cost and technical challenges of setting up a distribution system that can hold such a molecule has led many to consider the deployment of decentralized refueling stations that generate hydrogen on-site. These are not cheap either, and without any vehicles on the road to use the fuel, there is no incentive to make the investment. The classic chicken-and-egg dilemma.

- **Storage:** The energy density of hydrogen is very low. To give a vehicle a competitive range (distance between refueling stops) it is necessary to store it at very high pressures or other means of densification. Development of cost-effective tanks to provide such storage is underway, but making certain that they are safe in all foreseeable accidents is a major challenge. Also, most parking garages and many bridges prohibit vehicles with compressed flammable gases. The access of vehicles fueled by hydrogen and other gasses to these structures needs to be addressed before full acceptance of these vehicles can be expected.

- **Refueling practices** associated with the various alternatives being explored for on-board storage would likely be different and more complex than those currently accepted for

[1] http://www.eere.energy.gov/afdc/infrastructure/station_counts.html

gasoline and diesel fuel. Standards for refueling systems and associated safe practices will need to be developed. With the current level of consumer expectations for self-service gasoline or diesel, refueling with hydrogen is likely to be anything but transparent to the consumer.

Increasing emphasis should be placed on the solutions to these challenges: low-impact production of hydrogen, creation of a hydrogen refueling infrastructure and solving the on-board fuel storage and refueling challenges. If these issues are addressed and the manufacturers incented to produce, and the consumer incented to buy, hydrogen-fueled vehicles using internal combustion engine technology, a fueling infrastructure will evolve that will cause basic market forces to bring more efficient fuel cell technologies to market when their major hurdles have been overcome.

Hybrids are transparent to the consumer and offer significant fuel savings to a limited number of vehicle owner/drivers. There are three major "rules" that govern where hybrids can offer financial payback to those who buy them:

1. **The duty cycle must be highly transient**. In other words, there must be a lot of stop and start to really maximize the savings of the hybrid powertrain. Hybrids work by capturing energy normally expended in the brakes and recycling it to assist the engine as it accelerates the vehicle. If there is very little opportunity for energy capture, there is very little opportunity for energy savings with the hybrid.
2. **Fuel use must be high**. That is, the distance traveled in a year must be large so that there exists an opportunity for financial payback.
3. **An opportunity should exist to offset high brake maintenance** costs with the hybrid, adding to the financial incentives to adopt the technology.

For most consumers, fuel prices will have to be much higher before there is payback for the extra cost of the hybrid technology. Indeed, it is generally accepted that hybrids present a poor financial case for the average consumer.[2] As the cost of batteries declines with advances in technology and market volumes, we expect that this payback period will be reduced. However, used vehicle residual values due to questions about battery condition and the still high cost of mature replacement batteries (we estimate about $1,500 based on discussions with battery chemists) will curtail widespread adoption of hybrids. Moves by the manufacturers to alter the image of hybrids from purely "green' technologies to the position of a performance option (performance without guilt) are, in our view, attempts to put forth a more favorable value proposition, focusing on the competitive core value of the Baby Boomer population.

Plug-in hybrids alter these rules somewhat, but are still duty-cycle sensitive. Those who drive out of range of the charge provided from the grid will experience a penalty associated with the

[2] Peter Valdes-Dapena, *Best cars with great gas mileage*, CNNMoney.com, May 8, 2006: "We've selected five -- a luxury car, family sedan, sports car, crossover SUV and a subcompact -- that are smart buys and easy on fuel. For each category, we've also mentioned two alternatives.
None of the top cars are hybrids. That's because, with their added cost, hybrids aren't really a good value from a purely economic standpoint. But we've provided a hybrid choice in some categories for those who are willing to pay more to burn less fuel."

added weight of the additional batteries needed to store the grid power. Those who drive on pure-electric power close to the point of recharge are also driving less efficiently than possible because they are carrying around the unused internal combustion engine and related systems during the battery-only portion of the duty cycle. Questions of residual value due to battery issues are apt to be at least as acute as with non-plug-in hybrids. While most consumers may actually drive in duty cycles within the range afforded by the plug-in hybrid, their mindset is that they need a vehicle with a full 300 mile range, and have no good reason to give up or exchange this expectation with something else.

There are some arguments that hybrids offer fuel savings on the highway due to their downsized engine, and that the extra power needed for acceleration can be obtained from the batteries. This is indeed the case. However, those who actually drive on the highways most of the time, or those who think they do and hence evaluate their car accordingly, can receive an equal or larger fuel economy boost at much lower initial cost with a downsized and turbocharged gasoline engine, which is also of significant benefit in the city.[3]

In sum, hybrids make the most sense in urban commercial applications where many miles are accumulated each year in stop and go traffic. The most attractive application are on heavy vehicles such as refuse trucks and urban buses where the financial savings due to a reduction in brake maintenance costs can help provide a payback to the hybrid.

Their exists a viable alternative to the hybrid technology that is far less sensitive to the way it is driven, and that has much less of a residual value risk, yet offers an equal if not greater fuel economy and performance benefit: the diesel engine. The diesel has been challenged to meet the emission regulations. However, technology is advancing and we believe that there exists a high probability that further reductions in emissions beyond the current Tier 2 standards are possible.

There remains a great deal of uncertainty over the future of emissions regulations beyond Tier 2. We believe that the vehicle manufacturers are reluctant to invest in manufacturing facilities for these engines based on a business case for the U.S. market due to this uncertainty. Policy makers could move the situation forward by giving a clear signal to the auto makers as to the level of post-Tier 2 emission standards. Technology developments and investments could then be made based on calculable risks rather than a very uncertain future governed by the unknown future of emissions regulation.

Recent market acceptance of diesel-powered cars and light trucks suggests that the historic U.S. market reluctance towards the diesel no longer exists. The remarkable acceptance of diesel technology in Europe, where the diesel market share exceeds 50% of the new car fleet, further supports this view.

[3] Global Insigbt Inc. and TIAX LLC, *Future Powertrain Technologies, 2008 to 2020*, published 2001. Downsized and turbocharged gasoline engines yield about a 20% reduction in fuel consumption, or about the same benefit as a mild hybrid, when modeled over the FTP-75 test cycle.

Recent Market Acceptance of the Diesel
Exceeded the Expectations of Vehicle Manufacturers

Diesel Vehicle	Sales Expectations	Actual Sales	% Difference
Jeep Liberty	5,000	10,000+	100%+
Mercedes Benz E320	3,000	4,158	38%
VW US Diesel Sales (April 2006)	2,219	4,516	103%

Sources: Jeep: PR Newswire, 22 March 2005, E320: PR Newswire, 3 May 2005: VW: Green Car Congress, 8 May 2006

Question 2b:
How more or less likely is it that these radically new technologies – fuel cells, electric drive trains, or significant battery storage capabilities, for example – will be incorporated into cars rather than incremental innovations to internal combustion engines?

Historically, 'radical' technologies like these have not been incorporated in the vehicle fleet, primarily because they are not transparent to the consumer when assessed on the basis of one or more of the criteria of cost, utility and/or convenience. Incremental changes and innovations have been the experience – evolutionary rather than revolutionary

These and other advanced technologies offer further incremental improvements in fuel consumption. They will be adopted by the marketplace if and when they can meet the expectations of the core values of the consumers. Each of these, and indeed other innovations, are challenged to equal the current end expected evolution of the performance of the internal combustion engine. Concurrent achievement of competitive cost (initial and/or life-cycle), range, refueling time, all-weather performance, well-to-wheels efficiency and greenhouse gas emissions etc. remain significant challenges.

The likelihood that these technologies can be incorporated into cars can be increased by also working through public education programs to influence the formation of core values of future generations, as discussed above. The best chance of this happening long term is via Generation Z and their Gen X parents(who tend to have a more altruistic bent than other generations. By definition, it is impossible to change the core values of the current generations of consumers, but one can possibly modify consumer behavior by putting the benefits and shortcomings, if any, of these technologies into proper juxtaposition with current consumer core values, again through education. Incorporation of the technologies into cars will occur as both the technology and consumer perceptions evolve towards each other.

Regardless of how the end-result is achieved, we forecast that increases in efficiency of the vehicle through available or non-disruptive powertrain technologies will reach the point of diminishing returns once an improvement of approximately 30% has been

achieved when compared to a baseline gasoline engine. To obtain improvements greater than this will require the use either alternative fuels or inherently more efficient lighter vehicles.

Summary:
What would be required to lead automakers to apply technology advancements to improving fuel economy?

The automotive industry will respond to increased demands for fuel economy from the consumer. Changes in consumer behavior that place a higher priority on fuel economy will result in the increased deployment of presently-available technologies such as hybrids, downsized and turbocharged gasoline engines, displacement on demand, etc.

A clear regulatory position on the future of emissions standards beyond Tier 2 will enable manufacturers to make an assessment of the likely future prospects for regulatory acceptance of the Diesel – the one technology that meets all current consumer expectations for performance while delivering a 20 to 30% improvement in fuel economy.

Changes in consumer behavior can be expected if and when the need for fuel consumption reduction resonates better with the core values of the consumer. The bulk of today's car buying public places high priority on the need for economic, physical and social survival. With current fuel prices and availability, fuel consumption has a lower priority than other vehicle attributes such as a high seating position (which increases aerodynamic drag), faster acceleration (that usually results in an engine that operates at of-peak efficiency most of the time) and high perceived levels of mobility and safety (that result in vehicles heavier than might normally be necessary).

Policies in the U.S. have lacked from the very beginning any component that attempts to change consumer behavior. Emphasis has been placed instead on maintaining mobility and lifestyle in a business-as-usual consumer environment.

What is needed is a series of coordinated efforts, all aimed at conservation. Programs that sponsor the development of high-risk technologies need to be continued simultaneously with public education programs that increase public awareness of the need to conserve, and to make it in their best interests to do so. It is likely that the high-risk technologies will have some limitations, or will change to some extent the normal expectations of today's vehicles with respect to range, refueling, convenience and performance. The core values of future consumer generations can be influenced by including in the education of current school-age children the need to conserve energy in all forms so that they embrace the new technologies and their differences from the vehicles of today.

Education programs need to be reinforced with fiscal programs that are in alignment with conservation goals. Programs that tax excessive consumption and reward conservation for new vehicles as well as those in-use will provide additional incentives to conserve.

What hurdles must hybrids, flex fuel, and hydrogen-powered vehicles clear before the automobile industry, industry analysts, and the automotive press accept these technologies and consumers buy them?

Without a change in consumer values, transparency is the primary condition that must be met for the consumer to adopt a new technology in today's marketplace. Cost, reliability, durability, range, refuel time and convenience all need to be equal or better than the technology we seek to replace.

Hybrids suffer from higher costs, both initial and life-cycle, as their fuel economy is generally insufficient to give a payback to the original purchaser during the first ownership period, and battery life issues cloud the resale value.

Hydrogen vehicles present a host of range, refueling and access challenges in addition to the technical issues and uncertainty of a net benefit when well-to-wheels issues are considered.

Of the three technologies mentioned, Flex-Fuel vehicles offer the one technologically transparent solution, but only because the ethanol-containing fuel is not required. To make a difference in energy consumption, the 6 million FFVs on the road must have access to E85 at competitive costs. At the moment, there are less than 700 E85 stations nationwide, versus 175,000 refueling sites for conventional fuels.

How more or less likely is it that these radically new technologies – fuel cells, electric drive trains, or significant battery storage capabilities, for example – will be incorporated into cars rather than incremental innovations to internal combustion engines?

Historically, 'radical' technologies like these have not been incorporated in the vehicle fleet, primarily because they are not transparent to the consumer when assessed on the basis of one or more of the criteria of cost, utility and/or convenience. Incremental changes and innovations have been the experience – evolutionary rather than revolutionary

They will be adopted by the marketplace if and when they can meet the expectations of the core values of the consumers. Concurrent achievement of competitive cost (initial and/or life-cycle), range, refueling time, all-weather performance, well-to-wheels efficiency and greenhouse gas emissions etc. remain significant challenges.

Because it appears likely that these technologies will be accompanied by changes in these characteristics, the likelihood that these technologies can be incorporated into cars can be increased by also working through public education programs to influence the formation of core values of future generations, thus changing the willingness of the consumer to accept changes.

Regardless of how the end-result is achieved, we forecast that increases in efficiency of the vehicle through available, non-disruptive powertrain technologies will reach the point of diminishing returns once an improvement of approximately 30% has been achieved when compared to a baseline gasoline engine. To obtain improvements greater than this will require the use either alternative fuels or inherently more efficient lighter vehicles.

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Phil Gott is a Director for Automotive Consulting within the Automotive Group of Global Insight, Inc. He specializes in identifying technical/competitive advantages, and creating and implementing technical, business and/or market entry strategies to exploit them and achieve targeted business results. He has served the automotive industry since 1975 and has conducted a number of technology and market assessments or developed market entry strategies for many light vehicle technologies, including powertrain, electronic and mechanical systems as well as advanced materials.

Phil has primarily helped automotive vehicle manufacturers and component suppliers deal with the continuing changes in the automotive industry, whether the changes have been driven by regulatory, competitive or market forces. He both manages and participates in market research projects in which he has identified new product and market opportunities for component suppliers in the powertrain, driveline, chassis and suspension areas. He has managed major programs for vehicle manufacturers, providing the foundation for their long-term powertrain strategy. His work has also provided input to EPA, DOT and NASA on programs that support the development of regulatory standards, or assessing their impact. He has identified the need for, and led major multiclient studies assessing the likely changes in vehicle powertrain and electrical systems. To accomplish these, Phil draws upon his quarter century of industry experience, his mechanical engineering training (BS from Lafayette College) and his hands-on experience which includes building and testing experimental vehicles; designing, managing the construction and operation of one of North America's most advanced engine development laboratories; and preparing and developing five race cars, four of which are national or regional champions. He is a member of the Society of Automotive Engineers and the honorary engineering fraternity, Pi Tau Sigma. He also holds an SCCA National Competition license, campaigning an Acura Integra in the Northeastern U.S.

Phil has authored a number of industry publications including the award winning *Changing Gears*, a 400+ page history of the automotive transmission and how the industry responded to different market, societal and business forces to develop new transmission technologies. This hardbound book was published by the Society of Automotive Engineers in 1991

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